MULTIELEMENT CONODONTS FROM THE ESTILL SHALE (SILURIAN) OF SOUTHERN OHIO

A Thesis Presented in Partial Fulfillment of the Requirements for the Degree Bachelor of Science in the College of Mathematics and Physical Sciences of the Ohio State University

By

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ABSTRACT

Conodonts from the Estill Shale (Lower Silurian) are identified using both form taxonomy and multielement taxonomy. Multielement apparatuses of two species, *Ozarkodina polinclinata* (Nicoll & Rexroad), as proposed by Cooper (1977), and *Carniodus carnulus* Walliser, as proposed by Walliser (1964), are examined in detail. Additional sources containing information about the occurrences of the elements of the two apparatuses are added to information from this study. Indices of affinity of the elements for each other are calculated using these data. The apparatus of *O. polinclinata* is corroborated. The apparatus of *Carniodus carnulus* of Walliser is reconstructed and two new elements are added.

INTRODUCTION

I undertook the study of the conodonts from Estill Shale for a number of reasons. I felt that it would be to my benefit to work on a project that would require that I become familiar with all the stages involved in the collecting, processing, picking and identifying of samples that are necessary in the study of conodonts. The Estill Shales not only fulfilled that requirement, but also provided both a unique and challenging research experience.

To the best of my knowledge, even though the conodonts from the Estill had been studied before, (Rexroad & Nicoll, 1972) never before had anyone been given the chance to collect from a complete section at one locality, only incomplete sections at widely scattered localities. Recent roadwork on U.S. 41 in Adams County, Ohio, presented me with just that opportunity, for a roadcut made to reroute the highway resulted in the exposure of the formation, from the basal portion overlying the Dayton Limestone to the top, which is overlain by the Bisher Formation. I could not resist the opportunity, for I was afraid that if I waited too long, the exposure might become just another grassy hillside.

Finally, at least as far as the Department of Geology & Mineralogy at O.S.U. is concerned, I would be working in practically unexamined strata, for not much previous research had been done in Ohio on deposits of Silurian age younger than the Brassfield Formation, which Cooper (1975) considered to be in the Distomodus kentuckyensis Zone of the Llandovery. The Estill is considered to be mainly in the *amorphognathoides* Zone of Walliser (1964) by Rexroad *et al*. (1965).

I began my project uncertain as to whether or not I would be able to accomplish my goal. I wanted to find out what species of conodonts were present in the Estill and to be able to add to, or verify, previous reconstructions of multielement species from work on contemporaneous strata. I had no idea what the productivity of the samples would be, however, and even though I collected fairly large samples, all well over 2 kilograms, it was not until after I actually picked out the conodonts that I knew I could work toward my goal.

My samples were not very productive, four yielding no identifiable conodonts at all, and only one yielding more than 100 identifiable conodonts. My information alone would have been insufficient for any comprehensive work, but the addition of information from other studies on the Estill and other contemporaneous strata has made it possible for me to acknowledge the occurrence of several well-described species in my material. In addition, I am able to verify Cooper's (1977) reconstruction of the apparatus of Ozarkodina polinclinata (Nicoll & Rexroad) and also to suggest a reconstruction of the apparatus of Carniodus carnulus (Walliser, 1964, Apparatus D).

PREVIOUS RESEARCH ON CONODONTS FROM LOWER SILURIAN STRATA

Many publications have dealt with conodonts from the Lower Silurian, including one dealing specifically with the Estill Shale.

Rexroad & Nicoll (1972) concerned themselves solely with the Estill Shale, basing their observations on specimens from seven collecting localities in Kentucky and Ohio (see Figure 1). They recognized four multielement groups of conodonts in the Estill, but they also presented many reasons why they felt the groupings failed to represent valid reconstructions of multielement apparatuses. In an earlier publication, Nicoll & Rexroad (1969) described a fauna contemporaneous with that of the Estill from the Salamonie Dolomite in southeastern Indiana and adjacent parts of Kentucky. The Salamonie Dolomite and Estill Shale are considered to be facies of a once-continuous sedimentational unit (Rexroad & Nicoll, 1972).

Cooper (1976) described multielement species from the St. Clair Limestone of southern Illinois, the lower part of which he considered indicative of the amorphognathoides Zone (Zone III) of Walliser (1964), therefore, making it equivalent in age to the Estill according to Rexroad et al. (1965). Cooper (1977) described multi-element reconstructions of several species that are represented in both Rexroad & Nicoll's (1972) and my collections from the Estill.

Two other publications, one by Aldridge (1972) and one by Walliser (1964) also contain collections of conodonts of the amorphognathoides Zone of Walliser (1964). The collections come from the Welsh borderland and the Carnic Alps, respectively.

Cooper (1975) and Branson & Mehl (1933) also describe conodonts from the Lower Silurian.

METHODS OF STUDY

I collected all of the conodonts for this study from a complete section of the Estill Shale recently exposed in a roadcut on the east side of U.S. 41 about 2 miles south of Peebles in Adams County, Ohio (Peebles 7.5 minute Quadrangle, 1974 photo revised) (also see Figure 1). I began sampling in a drainage ditch about 0.2 miles south of a "Slow Traffic - Keep to Right" sign.

I used a Jacob staff and a Brunton compass as a hand level to aid me in collecting samples at 2-meter intervals throughout the section (see Figure 2 for the measured section and lithology). In addition to collecting samples from the Estill, I also collected samples from the Brassfield Formation and the Bisher Formation in my basal and top samples respectively. In the 28, 32 and 34 meter intervals I collected 2 samples, one from the shale and another from the calcareous siltstone beds located just below the shale. In order to collect another calcareous siltstone, I skipped the 36 meter interval and measured up to 37 meters, again collecting both shale and siltstone samples. Since the next 2-meter interval was grass-covered, I measured up 0.5 more meters to 39.5 meters for my highest Estill sample. The next sample came from the Bisher Formation, which was only 0.5 meters above the last. I collected an average of 3.20 kilograms for each sample.

I processed the shale samples by soaking them overnight in kerosene, draining off the kerosene the next day, and then soaking them in hot water. I washed the slumped shales through 40- and 100-mesh screens and washed the residues from the 100-mesh screen into a beaker. I added a small amount of sodium bicarbonate to the beaker, along with hot water. I rapidly stirred the solution to separate as much of the remaining clay as possible. I washed this mixture through the 100-mesh screen. I filtered the 100-mesh screen residue, allowed it to dry, then "baked" it and the 40-mesh residue on paper in separate aluminum pans in an oven calibrated at 125° C.

I followed the same procedures for processing the limestone, dolomite and calcareous siltstone samples, with two exceptions. I reduced these samples by suspending them in a well-perforated small

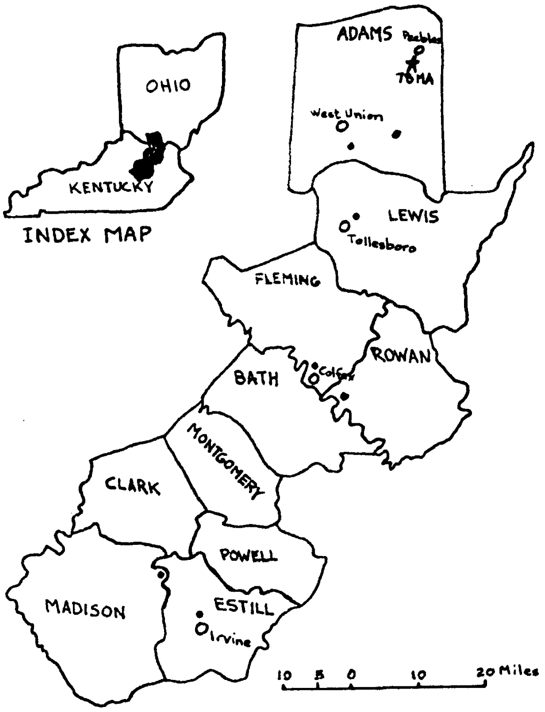

Figure 1 – Locality map of Ohio and Kentucky showing the locations where Rexroad & Nicoll (1972 - marked with a •) and Kleffner (1978 - marked with a ★) collected samples from the Estill Shale. For precise location of the Kleffner section see text.

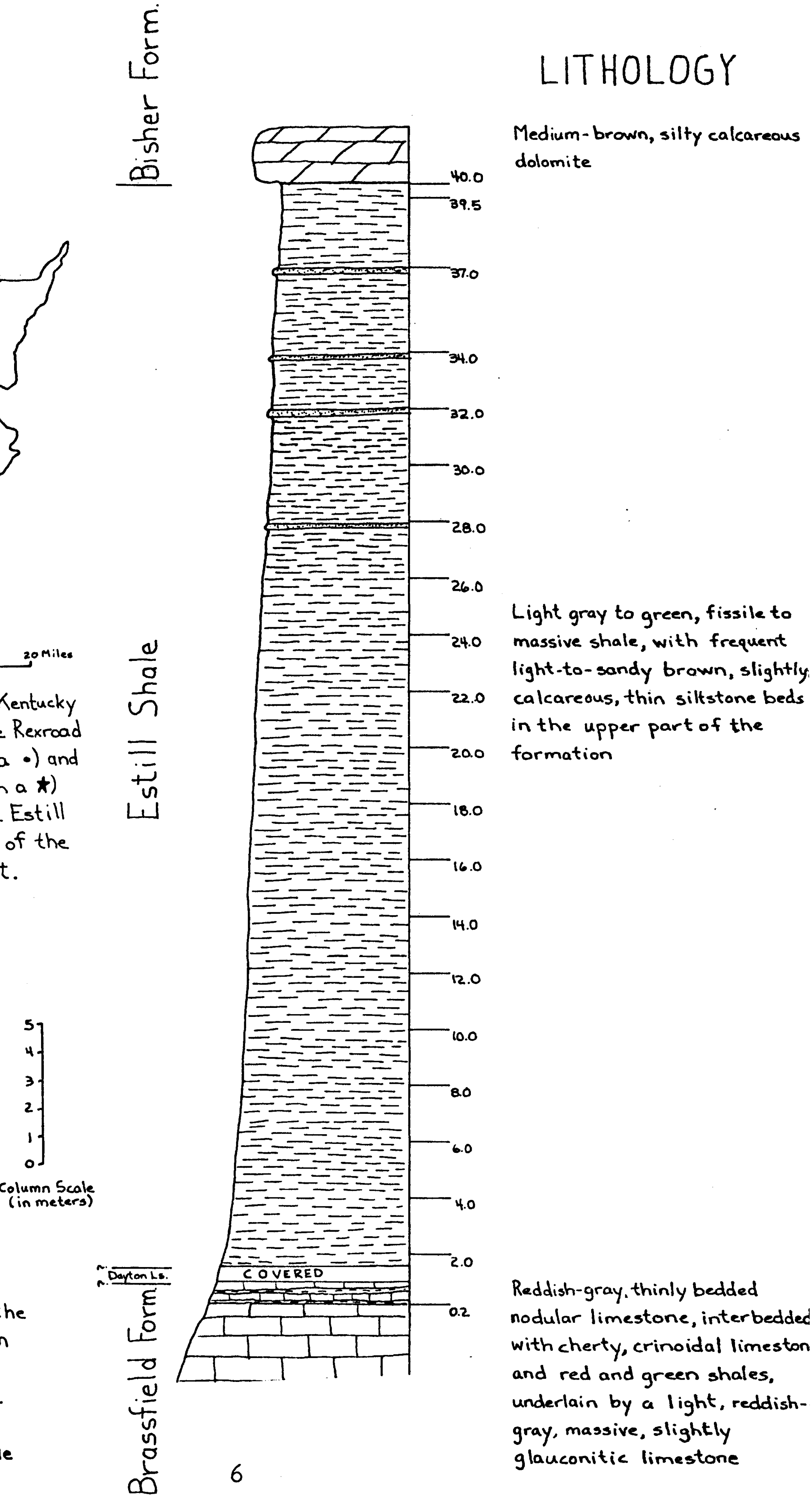

Figure 2 - Measured section of the Estill Shale at location 78MA (see figure 1). Collection sites are indicated by markers on the right-hand side of the column.

bucket in a large bucket filled with hot water and 750 ml. of glacial acetic acid. Another exception was that whereas I used the entire shale samples for reduction, I reduced only 1-kilogram samples of the Brassfield and the siltstone and 1.5 kilograms of the Bisher Dolomite.

I used magnetic separation to divide my residues into magnetic and nonmagnetic fractions.

I did not use a computer to determine the groupings for the multielement species. Instead, I chose the two most abundantly represented species from my material (excluding _Panderodus_) that had been already reconstructed. I added the data about the same species from several other publications (Walliser, 1964; Nicoll & Rexroad, 1968; Rexroad & Nicoll, 1972; Aldridge, 1972) to mine. I used the combined data about the occurrences of the elements of the species and a formula for the index of affinity from Kohut (1969), as proposed by Fager & McGowan (1963) to determine the affinity of the elements of the species for each other.

THE CONODONT FAUNA

My samples, including the Brassfield and Bisher samples, yielded 301 identifiable conodonts, 94 comprising probably two species of _Panderodus_. The remaining conodonts comprise 29 species of 13 genera in form taxonomy (see Table 1) and consist of elements of probably 11 species of 7 genera using multielement classification.

All but four of the conodont species represented in my collection are also represented in the collection of Rexroad & Nicoll (1972). _Pseudooneotodus_ _beckmanni_ (Bischoff & Sannemann) and _Pseudooneotodus_ _bicornis_ Drygant are both found in my collection, but are not mentioned in Rexroad & Nicoll (1972), quite possibly because many do not feel that they are truly conodonts. However, Cooper (1977) describes them as a species having a monoelemental apparatus. My collection also contains Ozarkodina media and Hindeodella equidentata, but specimens of both of these are found only in sample 78 MA-40, the sample from the Bisher Formation, therefore explaining why they are not found in Rexroad & Nicoll's (1972) paper on the Estill.

The most abundant conodonts in my samples, as in the samples of Rexroad & Nicoll (1972) are elements of Panderodus. The Pa element of Ozarkodina polinclinata (Nicoll & Rexroad), Spathognathodus polinclinatus is the second most abundant conodont found in my collection, as compared to the Pa element of Pterospathodus amorphognathoides, which is the second most abundant in Rexroad & Nicoll (1972)

Overall, the Estill proved to be unproductive as far as conodonts are concerned, but there are horizons in the formation that are productive, particularly the interval between 16 and 24 meters, which yielded over half of the identifiable conodonts. In the 7 samples taken between 24 meters and the base of the Bisher there was a total of only 19 identifiable conodonts. This part of the formation is also marked by the occurrence of many siltstone interbeds, which increase in frequency toward the top of the formation. The siltstone beds mark a change in environment that may have been unfavorable to conodonts. Both Rexroad et al. (1965) and Rexroad & Nicoll (1972) mention that Zone III conodonts disappear in the upper part of the Estill and that an ostracode is used for dating purposes, implying that there must be a lack of conodonts in their upper samples also.

TABLE 1

Stratigraphic Distribution of Conodonts from the Estill Shale Using Form Element Taxonomy

SPECIES	SAMPLE NUMBERS																				
	0.2	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	37.0	39.5	40.0
Acodus curvatus				1					1												
Carniodus carinthiacus			1						2		4	2	2								
Carniodus carnicus									2												
Carniodus carnulus			1	1					2		3	1									
Carniodus carnus									2												
Distomodus egregria	1								2							2					
Distomodus extrorsus		1																			
Distomodus kentuckyensis		1							4												
Exochognathus brassfieldensis							1		2		2										
Exochognathus caudatus									1				1								
Exochognathus espansus									1		1					2					
Hadrognathus staurognathoides			6								1	1		2							
Hindeodella equidentata																					3
Ligonodina variabilis						1			20	1											
Neoprioniodus costatus							1		2	1			1			1					
Neoprioniodus planus	1						1		10												
Neoprioniodus subcarnus										1											
Ozarkodina gaertneri						1			7				1								
Ozarkodina hanoverensis			2				1		9		1		1								
Ozarkodina media																					1
Panderodus costate	24			10					10		1		2			2				3	8
Panderodus simplexiform	13		1	4			1		4	1	2		1	2						1	4
Pseudooneotodus beckmanni			2									1									1
Pseudooneotodus bicornis			1				1		1		1			3							2
Pterospathodus amorphognathoides		2				3	3					2	5								
Spathognathodus celloni	1																				
Spathognathodus polinclinatus	1		4	1		4	2		14	3	2		1								
Spathognathodus ranuliformis																					1
Trichonodella asymmetrica	1								8			2						1			
Trichonodella excavata							1				1										
Trichonodella papilio								1	5												

CORRELATION

The age of the Estill Shale has already been well established by Rexroad _et al_. (1965) and Rexroad & Nicoll (1972) as being in Zones II and III of the Silurian, the _celloni_ and _amorphognathoides_ Zones of Walliser (1964). My specimens corroborate the dating.

Rexroad _et al_. (1965) and Rexroad & Nicoll (1972) appear to be slightly at odds concerning the dating of the upper part of the formation. Both acknowledge the occurrence of _Mastigobolbina typus_ in this part of the formation, and note that guide fossils of the _amorphognathoides_ Zone are rare in the upper part. Rexroad _et al_. (1965) suggest that it should be placed in Zone IV, whereas Rexroad & Nicoll (1972) indicate that the ostracode zone correlates almost exactly with the _amorphognathoides_ Zone according to Berry & Boucot (1970). My collection from the upper part of the Estill contains so few specimens, I cannot come to any definite conclusion concerning either dating. My basal Bisher sample contains both _Ozarkodina media_ and _Hindeodella equidentata_, elements of the multi-element species _Ozarkodina excavata_, which has a range from Wenlock to Lower Devonian according to Cooper (1976). Walliser (1964) lists the first appearance of _Ozarkodina media_ as occurring in the _patula_ Zone, the zone that follows the _amorphognathoides_ Zone. Based on this, I would be inclined to agree with Rexroad _et al_. (1965) and place the upper part of the formation in Zone IV, the _patula_ Zone.

SYSTEMATIC PALEONTOLOGY

There are so few specimens in my collection that there is only one sampling interval in which I have the complete apparatus of a multielement species. My samples included elements from a number of conodont apparatuses.

The apparatuses are Walliserodus curvatus (Branson & Branson), Panderodus sp. cf. P. serratus Rexroad, Hadrognathus staurognathoides Walliser, Pseudooneotodus bicornis Drygant, Pseudooneotodus beckmanni (Bischoff & Sannemann), Ozarkodina polinclinata (Nicoll & Rexroad), Ozarkodina excavata (Branson & Mehl), Ozarkodina ranuliformis (Walliser), Pterospathodus amorphognathoides Walliser, Pterospathodus celloni (Walliser), Carniodus carnulus Walliser, and an Oulodus species.

Most of these species have already been well described by Cooper (1975, 1976, 1977) and Walliser (1964). Since I have so few specimens of most of these species and they have been thoroughly described already, I have nothing novel to add about any of the apparatuses except for two of them. I have a complete apparatus of Ozarkodina polinclinata and almost a complete apparatus of Carniodus carnulus, both in the same sample, 78 MA-16.0. Disregarding Panderodus, the elements of O. polinclinata and C. carnulus were the most abundant conodonts in my collection. The information from my collection added to that of previous studies on contemporaneous strata is ample evidence for me to comment on the reconstructions of the apparatuses of the two species and to add two more elements to the apparatus of C. carnulus of Walliser.

All of the illustrated specimens will be catalogued and then stored in the Orton Museum of Geology at the Ohio State University. The remainder of the collections from the section are kept in the

TABLE 2

PART A- Stratigraphic Distribution of the Elements of _Ozarkodina Polinclinata_ and _Carniodus Carnulus_ from My Collections in the Estill Shale

PART B--Stratigraphic Distribution of the Elements of _Ozarkodina Polinclinata_ and _Carniodus Carnulus_ from Both Rexroad & Nicoll's (1972) and My Collections in the Estill Shale

Species	Sample Number																				
Part A	0.2	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	37.0	39.5	40.0
Ozarkodina polinclinata																					
S_a								1	5												
S_b	1								8			2						1			
S_c						1			20	1											
P_a	1		4	1		4	2		14	3	2		1								
P_b			2				1		9		1		1								
M	1						1		10												
Carniodus carnulus																					
C. carnicus									2												
C. carnus									2												
C. carnulus			1	1					2		3	1									
C. carinthiacus			1						2		4	2	2								
Neoprioniodus costatus							1		2	1			1			1					
Neoprioniodus subcarnus										1											
Part B																					
Ozarkodina polinclinata																					
S_a	5	2	1		1			1	5	3											
S_b	15								8	1		2						1			
S_c	16		4			1	1		21	5	1		1						1		
P_a	88	4	8	2	4	4	3	1	19	16	2	1	4	1							
P_b	35		4		3		4	1	13	8	2		2								
M	18		5	1	1		1		13	4											
Carniodus carnulus																					
C. carnicus	2	2	1		1	1		2													
C. carnus	1	4	4		4				5	2		1	1								
C. carnulus	2	7	3	1	1		2	1	6	5	4	4	3	3					1		
C. carinthiacus	5	3	5	1	3	1			3	3	4	4	2	2							
Neoprioniodus costatus	4	3	4				1		1	2	1	1	1			1					
Neoprioniodus subcarnus	4	3		1	2		1	1	3	3				2							

Micropaleontological Laboratories of O.S.U. under the prefix 78 MA.

Ozarkodina polinclinata (Nicoll & Rexroad)

Plate 1, figures 15 - 20.

Pa element
Spathognathodus polinclinatus Nicoll & Rexroad. Nicoll & Rexroad, 1968, p. 60, pl. 2, figures 19, 20; Aldridge, 1972, p. 214, pl. 4, figure 13; Rexroad & Nicoll, 1972, Pl. 1, figures 35-38.

Pb element
Ozarkodina hanoverensis Nicoll & Rexroad. Nicoll & Rexroad, 1968, p. 50, Pl. 2, figure 9; Aldridge, 1972, p. 200, Pl. 5, figure 1; Rexroad & Nicoll, 1972, Pl. 1 figures 31-33.

M element
Neoprioniodus planus Walliser. Nicoll & Rexroad, 1968; p. 41, Pl. 5, figures 11, 12; Rexroad & Nicoll, 1972, Pl. 1, figures 39-41.

Sa element
Trichonodella papilio Nicoll & Rexroad. Nicoll & Rexroad, 1968, p. 65, Pl. 4, figures 4-6; Rexroad & Nicoll, 1972, Pl. 2, figure 28.

Sb element
Trichonodella asymmetrica Nicoll & Rexroad. Nicoll & Rexroad, 1968, p. 62, Pl. 4, figure 7; Aldridge, 1972, p. 217, Pl. 7, figure 17; Rexroad & Nicoll, 1972, Pl. 2, figure 30.

Sc element
Ligonodina (?) variabilis Nicoll & Rexroad. Nicoll & Rexroad, 1968, p. 39, Pl. 4, figures 12-14; Aldridge, 1972, p. 189, Pl. 8, figure 14.
Hindeodella cf. H. confluens Branson & Mehl. Rexroad & Nicoll, 1972, Pl. 1, figure 34.
Complete apparatus
Ozarkodina polinclinata Nicoll & Rexroad. Cooper, 1977, p. 1059, Pl. 1, figures 11, 13-15, 17-18.

Description

Pa element - This element has already been described in form element taxonomy as Spathognathodus polinclinatus.

Pb element - This element has been described as Ozarkodina hanoverensis.

M element - This element has been described as Neoprioniodus planus Walliser by many, including Walliser (1964), Aldridge (1972) and Nicoll & Rexroad (1969).

Sa element - Trichonodella papilio is the name given to this element in a description given in Nicoll & Rexroad (1969).

Sb element - Nicoll & Rexroad (1969) described this element as Trichonodella asymmetrica.

Sc element - Cooper (1977) described this as a hindeodelliform element. Descriptions of Ligonodina variabilis by Nicoll & Rexroad (1969) and of Hindeodella cf. H confluens Rexroad & Nicoll (1974) both fit this element.

Comments

Complete apparatuses of Ozarkodina polinclinata can be found in one of my samples, 78 MA-160(Table 2, Part A), and in two of the samples from the Estill in Rexroad & Nicoll (1972). Combining the data from Rexroad & Nicoll (1972) and my work, complete apparatuses can be found in the 0.2, 16.0 and 18.0 meter intervals (Table 2, Part B).

I combined data about the occurrences of the individual elements of Ozarkodina polinclinata from my work and that of Nicoll & Rexroad (1969) and Rexroad & Nicoll (1972). I determined the indices of affinity for each of the elements. Although Trichonodella papilio drops out at a level of 0.251 and Trichonodella asymmetrica drops out at a level of 0.328, this probably occurs as a result of the small number of conodonts in the three sources that I used for my calculations. The other four elements, Pa, Pb, M and Sc, remain grouped together to a level of affinity of 0.466 and the Pa, Pb and Sc elements remain grouped together to a level of 0.531. Taking everything into consideration, the small number of conodonts in the samples, the complete apparatuses in sample intervals in my material and in Rexroad & Nicoll's (1972) and the good indices of affinity, I corroborate the reconstruction of Ozarkodina polinclinata as proposed by Cooper (1977).

Range - Lower Silurian (L. celloni and P. amorphognathoides Zones) (Cooper, 1977).

Carniodus carnulus Walliser
Plate 1, figures 21-26.

Pa element
Neoprioniodus costatus costatus Walliser. Walliser, 1964, p. 48, Pl. 6, figure 14 and Pl. 28, figures 36-41; Aldridge, 1972, p. 193, Pl. 5, figure 22.

Neoprionioduss costatus Walliser. Nicoll & Rexroad (1968), p. 40, Pl. 5, figures 15, 16; Rexroad & Nicoll, 1972, Pl. 2, figures 8-11.

Pb element
Carniodus carinthiacus Walliser. Walliser, 1964, p. 31, Pl. 6, figure 8 and Pl. 27, figures 20-26; Nicoll & Rexroad, 1968, p. 24, Pl. 5, figures 1, 2; Aldridge, 1972, p. 168, Pl. 5, figures 8-10; Rexroad & Nicoll, 1972, Pl. 2, figures 1-3.
M element
Neoprioniodus subcarnus Walliser. Walliser, 1964, p. 51, Pl. 5, figure 7 and Pl. 28, figures 12-18; Nicoll & Rexroad, 1968, p. 41, Pl. 5, figure 10;
Aldridge, 1972, p. 195, Pl. 5, figure 17, Rexroad & Nicoll, 1972, Pl. 2, figures 6, 7.

Sa element
Carniodus carnicus Walliser. Walliser, 1964, p. 32, Pl. 6, figure 11 and Pl. 28, figures 8-11, Nicoll & Rexroad, 1968, p. 25, Pl. 5, figure 3; Aldridge, 1972, p. 168, Pl. 5, figure 11; Rexroad & Nicoll, 1972, Pl. 2, figures 4, 5.

Sb element
Carniodus carnulus Walliser. Walliser, 1964, p. 32, Pl. 6, figure 10, Pl. 10, figures 20, 21, Pl. 27, figures 27-38, and Pl. 28, figure 1; Nicoll & Rexroad, 1968, p. 25, Pl. 5, figures 4,5; Aldridge, 1972, p. 169, Pl. 5, figures 12-14; Rexroad & Nicoll, 1972, Pl. 1, figures 8-11.

Sc element
Carniodus carnus Walliser. Walliser, 1964, p. 34, Pl. 5, figure 3, Pl. 10, figure 13, Pl. 28, figures 2-7, and text-figure 4 y-z; Nicoll & Rexroad, 1968, p. 26, Pl. 5, figures 6-8; Aldridge, 1972, p. 169, Pl. 5, figures 15, 16; Rexroad & Nicoll, 1972, Pl. 1, figures 12, 13.

Description

Pa element - This element has been described as Neoprioniodus costatus costatus by Walliser (1964) and Aldridge (1972) and as Neoprioniodus costatus by Nicoll & Rexroad (1968).
Pb element - This element has previously been described as Carniodus carinthiacus. The blade widens laterally beneath the denticles, almost becoming a platform.
M element - This element has a prominent anticusp and has been described by other Silurian conodont workers as Neoprioniodus subcarnus.
Sa element - This nearly symmetrical to symmetrical element has been thoroughly described by Walliser (1964) and Aldridge (1972) as Carniodus carnicus.
Sb element - The element occupying this position shows considerable variation in the size relationship between the denticles and the cusp, the arching of the blade, and the inclination of the cusp. This element has been described by Walliser (1964) as Carniodus carnulus.

Sc element - This element was thoroughly described by Walliser (1964) as _Carniodus carnus_. In his description, he noted that there was a wide variation in the angle between the limbs of the blade and in the degree of inward curvature of the anterior limb.

Comments

No complete apparatuses can be found in any of my samples. Only the M element is missing, however, from the apparatus in 78 MA-16.0 (see Table 2, Part A). The combination of my data with that of Nicoll & Rexroad's (1972) results in complete apparatuses in both the 0.2 and 2.0 meter samples. In addition, the 16.0 and 18.0 meter samples only lack the Sa element (see Table 2, Part B).

Walliser (1964) suggested that the apparatus of _Carniodus carnulus_ consists of 4 elements: _Carniodus carnulus_, _Carniodus carnus_, _Carniodus carinthiacus_, _Neoprioniodus subcarnus_. When I examined my collections, I noticed two other elements that looked like they belonged in the apparatus, based solely on appearance. They were _Carniodus carnicus_, and _Neoprioniodus costatus_.

In order to test this possibility, I calculated the affinity of the 6 elements for each other. I combined information listing the occurrence of the elements (Nicoll & Rexroad, 1968; Rexroad & Nicoll, 1972; Walliser, 1964; Aldridge, 1972) with mine. All of the elements remain grouped together until the affinity level reaches 0.377. Above this level the M element no longer groups with the Pa element. At the 0.418 level, the Sa element drops out. The 4 remaining elements remain grouped until the 0.487 level is reached. All of the elements have a strong affinity for some of the other elements in the apparatus. The highest level of affinity for each element is reported below.

The Pa element, _Neoprioniodus costatus_, 0.570, with the Sc element.

The Pb element, Carniodus carinthiacus, 0.589 with the Sb element.

The M element, Neoprioniodus subcarnus, 0.557 with the Sb element.

The Sa element, Carniodus carnicus, 0.529 with the Sc element.

The Sb element, Carniodus carnulus, 0.630 with the Sc element.

The Sc element, Carniodus carnus, 0.630 with the Sb element.

The 6 elements not only show high levels of affinity, but also occur together in the same stratigraphic range (see Walliser, 1964, Table 1 and Aldridge, 1972, Tables 1 & 3).

Range- Lower Silurian (Pterospathodus amorphognathoides Zone).

ACKNOWLEDGMENTS

I would like to thank Dr. Walter C. Sweet for all of his help, from the collecting of the samples to the writing of the manuscript. I also appreciated the help given by Jeff Franklin, who did a great job photographing my specimens. Finally, I would like to thank Barbara Kleffner for doing most of the typing for me.

The Department of Geology & Mineralogy, The Ohio State University made available a Cambridge S4-10 Scanning Electron Microscope. The "Friends of Orton Hall" reimbursed me for the production of the plate.

EXPLANATION OF PLATE 1

(All figures are Cambridge S4-10 scanning electron micrographs)

Figure 1	*Pseudooneotodus bicornis* Drygant. Top view, X 200, collection 78 MA-20.0.
Figure 2	*Oulodus* sp. Posterior view of Sa element (form species *Trichonodella excavata*), X 175, collection 78 MA-20.0.
Figures 3-5	*Panderodus* sp. cf. *P serratus* Rexroad. 3, inner view of recurved element, X 150, collection 78-MA-6.0; 4, inner view of simplexiform element, X 75, collection 78 MA-4.0; 5, inner view of costate element, X 90, collection 78 MA-6.0.
Figures 6-10	*Hadrognathus staurognathoides* Walliser. 6, lateral view of Sa element (form species *Exochognathus brassfieldensis*), X 90, collection 78 MA-20.0; 7, lateral view of M element (form species *Distomodus kentuckyensis*), X 75, collection 78 MA-16.0; 8, lateral view of Sc element, (form species *Distomodus egregia*), X 90, collection 78 MA-16.0; 9, top view of Pb element (form species *Exochognathus espansus*),X 100, collection 78 MA-20.0; 10, top view of Pa element (form species *Hadrognathoides staurognathoides*), X 100, collection 78 MA-4.0.
Figures 11, 12	*Pterospathodus amorphognathoides* Walliser. 11, lateral view of Pb element (form species *Ozarkodina gaertneri*),X 125, collection 78 MA-10.0; 12, top view of Pa element (form species *Pterospathodus amorphognathoides*), X 125, collection 78 MA-4.0.
Figures 13, 14	*Ozarkodina excavata* (Branson & Mehl). 13, lateral view of Pb element (form species *Ozarkodina media*), X 125, collection 78 MA-40.0; 14, lateral view of Sc element (form species *Hindeodella equidentata*), X 175, collection 78 MA-40.0.
Figures 15-20	*Ozarkodina polinclinata* (Nicoll & Rexroad). 15, posterior view of Sa element (form species *Trichonodella papilio*), X 180; 16, posterior view of Sb element (form species *Trichonodella asymmetrica*) , X 180; 17, posterior view of Sc element (form species *Ligonodina ? variabilis*), X 180; 18, lateral view of M element (form species *Neoprioniodus planus*), X 150; 19, lateral view of Pa element (form species *Spathognathodus polinclinatus*), X 120; 20, lateral view of Pb element (form species *Ozarkodina hanoverensis*),X 150; all specimens from collection 78 MA-16.0.

Figures 21-26 <u>Carniodus carnulus</u> Walliser. 21, lateral view of Sa element (form species <u>Carniodus carnicus</u>), X 190; 22, lateral view of Sb element (form species <u>Carniodus carnulus</u>), X 160; 23, lateral view of Sc element (form species <u>Carniodus carnus</u>), X 110; specimens 21-23 from collection 78 MA-16.0; 24, lateral view of Pb element (form species <u>Carniodus carinthiacus</u>), X 175, collection 78 MA-20.0; 25, lateral view of Pa element (form species <u>Neoprioniodus costatus</u>), X 110, collection 78 MA-24.0; 26, lateral view of M element (form species <u>Neoprioniodus subcarnus</u>), X 175, collection 78 MA-18.0.